*Einleitung in die Geologie als historische Wissenschaft.* By Johannes Walther. Jena, 1893–4.

In this new work of Professor Walther the inductive method receives a new and highly interesting treatment in its application to historical geology. There are, we are told, four principal methods of attacking the historical phases of geology, (1) the astrophysical method which begins with the earth as star-dust and studies its development from the speculative and mathematical standpoint of the astrophysicist; (2) the tectonic method which studies the structure of the crust and strives to reconstruct therefrom the changes which have taken place in it; (3) the experimental method in which geological phenomena are reproduced on a small scale in the laboratory; (4) the ontologic method.

The experimental method can, evidently, but rarely become a demonstration in the study of geologic phenomena, because we cannot often reproduce all the natural conditions and we know that the same results may often be produced by different methods. Thus coal may be procured by the rubbing or pressure of wood or by its imperfect combustion or by the action of acid upon cellulose tissue or by burning oil of turpentine. So also we may easily produce dolomite in the laboratory but to produce it from limestone and sea-water, observing the same conditions as those under which it is produced in nature has been the object of a great deal of unsuccessful experimentation. In many cases it is impossible for us to discover all the conditions under which the natural phenomena occur.

The experimental method must, therefore, be enlarged and at the same time held in check and corrected by a fourth method, the *ontologic method* as it is here called. This method consists in a word in making the earth our laboratory, in studying the processes by which geological history *is being made now*, and in making this study the point of departure for (introduction to) the study of historical geology. "We determine the origin of dead volcanoes by studying the formation of those now building; we form a basis for understanding the history of a fossil coral reef by examining a living reef; and the depth of water at which a fossil oyster bank was formed is approximated by a determination of the depths at which the genus *Ostrea* is now found living." (Introduction, p. xiii.)

Before entering further into the application of this method we

should bear in mind that like every other method it has limitations which the author does not fail to recognize. The most important of these seem to be the following: (1) Our observations of phenomena are often very limited. In spite of the numerous expeditions and deep sea dredging how small a fraction of the whole territory has been explored; (2) an important difficulty arises from the scattered condition of the literature of the subject which has been already greatly reduced by the present compilation; (3) more vital is the difficulty of studying forms which have no living representatives as the graptolites and the blastids and the fact that in general the farther back we go in geologic time the more difficult does it become to apply the ontologic method; (4) the most important limitation to this method, however, arises from the assumption which lies at the very root of it, namely, that factors affecting organic life and inorganic movement have remained the same in all ages. Can we be certain that the oyster now commonly found in from one to two hundred and fifty feet of water lived at the same depth in the Jurassic, or can we be sure that new factors have not entered in or old factors been lost which affected the mode of life and the deposition of strata? It becomes necessary then for the ontologically working historical geologist to be keenly alive to these possibilities of error and search in all his work to reduce the probable error to a minimum. If approached in this spirit this last objection would not prove as formidable as might at first be supposed and will decrease as *our knowledge of the laws of earth-history* become more and more complete.

Proceeding to the body of his theme the author agreeable to the nature of the ground to be covered divides his work into the study (1) of the formation of rocks, especially the sedimentary ones, (2) the mode of life of the marine organisms, and (3) the relations of the first to the second or the outside conditions of life and their effect upon the organisms (Bionomy); though for conventional reasons these topics are taken up in the reverse of this their more natural order.

Under the title "Bionomy of the Ocean" the author considers the distribution and conditions of life of marine organisms. As plants alone have the power to organize inorganic substances, it is important that we first study their conditions of life. They need light, water, carbonic acid, and chromophyll, without which the processes of assimilation cannot take place. As experiment has shown that light waves capable of

effecting chemical changes do not penetrate the water deeper than 400 meters and as the other conditions of assimilation are met above this line, it is proposed to distinguish a *diaphanic* region including the land and the water to a depth of 400 m. and inhabited by assimilating organisms and an *aphotic* region including the ocean and lakes below the assimilation-line and the dark caves of the crust, where plant life is impossible. Temperature limits—85° C. to 3° C. for water organisms—restrict greatly the distribution of life in the diaphanic region.

Upon a somewhat different basis of classification are next considered the life-zones of the ocean (divided first into oceanic basins and second into shore, shallow, and deep sea zones), and the kind of life inhabiting each (the author following Haeckel in dividing the ocean forms (Halobios) into Benthos, or bottom forms, Nekton or active, swimming forms and Plankton or passive, floating forms with numerous subdivisions).

Intimately connected with the question of environment in its relation to life is the facial development of the ocean bottom. Thus we find that certain forms as Mytilus and Mactra are found upon a mud bottom, other forms as Anomia and Spondylus love a gravel bottom. A change in bottom from any cause will cause a change in the fauna—a migration. The influence of the bottom extends, however, not only to the plants and animals living directly upon it but also to the Nektonic forms which feed upon certain plants and further to the animals of prey who live upon the animals (of both Benthos and Nekton) who frequent the same region. Further than this the fact that fish pick out a certain kind of bottom on which to lay their eggs causes them to frequent certain places during the spawning season.

A great many interesting questions relative to the effect of environment are discussed and by numerous facts illustrated in the following sections on the influence of light, of temperature, of salt percentage, and the effects of tides, waves, and circulation of the water upon the living organisms. The formation of oceanic islands and all those movements of the earth's crust which alter its position and cause a relative or absolute change in the sea-level have an immediate and vital influence upon all life within the region of change, because it affects at once the various conditions under which the organisms have been living. This constant change of environment by com-

pelling the faunas and floras to migrate, or die, or by modifications to adapt themselves to their surroundings becomes a powerful factor in the production of new varieties and the origin of new species.

Part II. takes up the mode of life of the marine fauna, especially from the standpoint of their importance to the palæontologic geologist. In order that the working geologist may not underrate the sources of error in his work the author very wisely discusses first the various zoölogic groups to show what ones are by reason of the absence or the unstable nature of the hard parts incapable of preservation. The following sections discuss for the most part the conditions favorable to the life of the various animals which are taken up in their zoölogic order beginning with the Foraminifera. In this section of the book the tables showing the maximum and minimum depths at which various species have been found by dredging are an especially prominent and valuable feature. In the section on the Cephalopods especial attention is called to the fact that the shells having air chambers by being able to float for long periods may be readily driven to great distances after the death of the animal and become fossils in a totally different region from that inhabited by the animal during life and in varying sorts of rock according to the nature of the bottom upon which the shell chances to drift. He points to the fact that the living *Spirula* and *Nautilus* are restricted to narrow boundaries on the sea bottom and that the animal is rarely seen. At the same time the shells of the dead *Nautilus* and *Spirula* are found widely scattered on tropical strands far from the home of the living animal. These thoughts applied to the very important fossil group of the Ammonites mean that their shells *tell us nothing* of the conditions under which the Ammonites lived but give us most valuable means of making exact correlations; for if as we suppose the Ammonite shell on the death of the animal rose to the surface and was carried for many days hither and thither and finally filled and sank, the shells would be scattered here and there over the entire ocean bottom and deposited in sediments *all of the same* age. So confident is the author of this that he believes that the Ammonite shells mark *not only homotaxial but actually homocronial periods.*

Part III. considers the formation of rocks upon the present surface of the earth. According to their mode of formation mechanical, chemical, volcanic and organic deposits are distinguished, and the distribu-

tion of the various rock facies over the earth's surface is indicated. This portion of the book which makes up the major part of Part III. (pp. 543–966) is largely systematic and classificatory in its nature and is filled with a large array of facts and observations on the formation of recent rocks and their distribution which cannot fail to be of great value to the working geologist. Here again the author calls brief attention to the alterations which the recent rock formations undergo in becoming fossil the knowledge of which is essential to the understanding of fossil deposits. Two classes of such changes are distinguished,—*metamorphism* and *diagenism*. By metamorphism is understood alterations caused by mountain pressure and volcanic warmth; and diagenism is defined (p. 693) as "all those physical and chemical changes which occur in a rock after its deposition without the action of mountain pressure and volcanic warmth." The book appropriately closes by outlining the possibilities of a *comparative lithology*. Throughout the book is urged the necessity of the historical geologist giving equal prominence to the study of the conditions of formation of the rocks and the conditions of growth of organisms. We make prominent the study of the correlation of faunas in historical geology and we should not neglect the study of the correlation of deposits. As comparative anatomy based upon the correlation of organs is the most important aid to palæontologic work of reconstruction, comparative lithology based upon the correlation of rock formations would prove a valuable aid to the study of historical geology and the reconstruction of earth history.

In the chapters on equivalence of the rocks, correlation of facies and changes in facies the author points the way to a scientific study of comparative lithology and lithological correlation of sediments and indicates some of the laws governing the deposit of sediments, which complicated as they are, are important enough to be worthy of careful investigation.

On the whole the work is a thoughtful and carefully worked out presentation of his theme, evincing long and careful work of observation and compilation and a just appreciation of the peculiar advantages and the disadvantages of ontologic methods of research in historical geology. The two factors—the history of fossils and the history of the rocks—are given equal prominence, and it is everywhere emphasized that the one cannot be studied successfully without the aid of the other.

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